

Chemical Bonding

OBJECTIVE #1: Know what a chemical bond is

A) Chemical Bond: the _____ forces that hold all molecules and compounds together

- atoms bond together for greater _____
 - o this is why noble gases in group 18 don't typically bond

This stability comes from an atom attaining an _____, which is having _____ valence electrons

- o atoms then become like a noble gas
 - metals _____ electrons and become like the noble gas in the _____ row
 - nonmetals _____ electrons become like the noble gas in the _____ row

OBJECTIVE #2: Know the energy changes when breaking and making bonds (B.A.R.F.)

A) To break a chemical bond, energy is _____ by the system

- this means that energy will be _____ (_____ thermic) when breaking apart 2 or more atoms

B) When forming a chemical bond, the energy that was absorbed to break the bond is now _____ (_____ thermic) by the system

Since the point of atoms bonding together is for stability, _____ bonds is favored over _____ bonds.

Bonding Introduction Questions

1. Which noble gas does nitrogen become like when forming a bond?

- a) helium b) neon c) lithium d) argon

2. Which noble gas does magnesium become like when forming a bond?

- a) helium b) neon c) sodium d) argon

3. Which kind of energy is stored in a chemical bond?

- a) potential energy b) kinetic energy c) activation energy d) ionization energy

4. Given the balanced equation: $\text{H}_2 + \text{energy} \rightarrow \text{H} + \text{H}$ Which statement describes what occurs during this reaction?

- a) energy is absorbed as a bond is formed c) energy is released as a bond is formed
b) energy is absorbed as a bond is broken d) energy is released as a bond is broken

OBJECTIVE #3: Know the three types of bonds that can be formed (T.I.C.S.)

The type of bond formed typically depends on the type of elements involved in the chemical bonding.

A) Ionic Bond: made up of one _____ and one _____

examples: NaCl, KBr, FeO, MgS

- the atoms in an ionic bond _____ valence electrons
 - o the metal atom always _____ electrons and becomes _____ charged; the nonmetal atom always _____ electrons and becomes _____ charged
 - o The oppositely charged ions then _____ one another

B) Covalent Bond (Molecular Substances): made up of two or more _____

examples: CO, H₂SO₄, CH₄, NO₂, Br₂

- the atoms in a covalent bond _____ valence electrons
 - o _____ between atoms can be equal or it can be unequal

C) Metallic Bond: made up of _____ only

Examples: Hg, Mg, Fe, Ni

- the atoms in a metallic bond _____ valence electrons equally among ALL metal atoms in a sample
 - o this phenomenon is known as a “_____” of mobile electrons

** It is possible to have a compound with both ionic and covalent bonding.

- The _____ bond needs a metal and nonmetal
- The _____ bond needs at least two nonmetals

Examples: Fe(OH)₂, MgSO₄, KC₂H₃O₂

1. Describe the following as ionic, metallic or covalent:

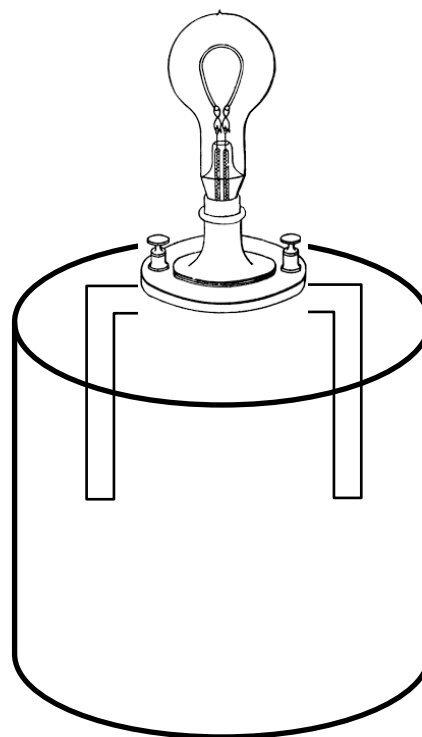
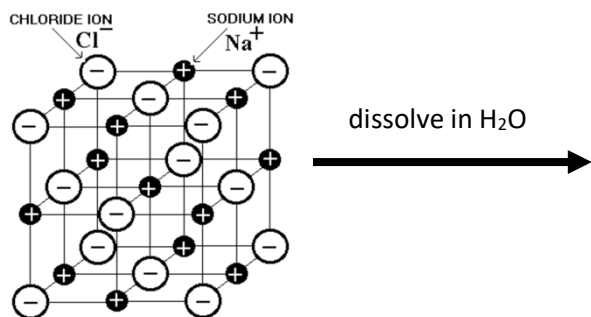
NaCl	_____	Al	_____	PI ₃	_____
CO ₂	_____	C ₆ H ₁₂ O ₆	_____	Ca ₃ (PO ₄) ₂	_____
Au	_____	Ti	_____	H ₂ S	_____
MgBr ₂	_____	KNO ₃	_____	Fe	_____
CH ₄	_____	H ₂ O	_____	K ₂ O	_____

OBJECTIVE #4: Know the properties for each type of chemical bond (@ room temperature)

A) Ionic Compound Properties

- _____ solids (sometimes called _____ solids)
- _____ melting points
- usually _____ in water
- only conduct electricity in _____ phase or when _____ due to *** _____, _____ particles ***

Molecule – Ion Attractions
 These attractions are found between water molecules and ions ONLY when IONIC COMPOUNDS dissolve in H₂O

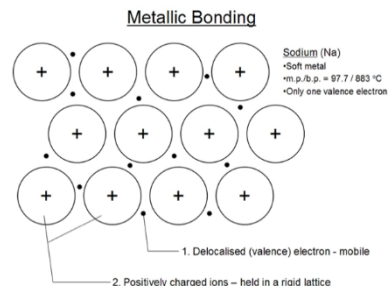


B) Covalent Compound Properties

- Solids are _____ and _____
- Can also be liquids or gases
- _____ melting and boiling points
- Can be both _____ or _____ in water
- _____ conduct electricity

C) Metallic Compound Properties

- all are solids except for _____
- _____ melting points
- _____ in water
- _____ conduct electricity due to freely moving valence electrons
 - “ _____ ” of mobile electrons



Bonding Property Questions

- Based on bond type, which compound has the highest melting point?
a) CH_3OH b) C_6H_{14} c) CaCl_2 d) CCl_4
- Which characteristic is a property of molecular substances with covalent bonds?
a) good heat conductivity c) low melting point
b) electrical conductivity d) high melting point
- A solid substance is an excellent conductor of electricity. The chemical bonds in this substance are most likely
a) ionic, because the valence electrons are shared between atoms
b) ionic, because the valence electrons are mobile
c) metallic, because the valence electrons are stationary
d) metallic, because the valence electrons are mobile
- The high electrical conductivity of metals is primarily due to
a) high ionization energies c) mobile electrons
b) filled energy levels d) high electronegativities
- A solid sample of a compound and a liquid sample of the same compound are each tested for electrical conductivity. Which test conclusion indicates that the compound is ionic?
a) Both the solid and the liquid are good conductors.
b) Both the solid and the liquid are poor conductors.
c) The solid is a good conductor, and the liquid is a poor conductor.
d) The solid is a poor conductor, and the liquid is a good conductor.
- Which sample of matter has a crystalline structure?
a) $\text{Hg}(\text{l})$ b) $\text{H}_2\text{O}(\text{l})$ c) $\text{NaCl}(\text{s})$ d) $\text{CH}_4(\text{g})$
- Which of the following solids has the lowest melting point?
a) $\text{H}_2\text{O}(\text{s})$ b) $\text{Na}_2\text{O}(\text{s})$ c) $\text{MgO}(\text{s})$ d) $\text{FeO}(\text{s})$
- Which type of substance is soft, has a low melting point, and is a poor conductor of electricity?
a) covalent solid b) ionic solid c) metallic solid d) network solid
- Which element consists of positive ions immersed in a "sea" of mobile electrons?
a) sulfur b) nitrogen c) calcium d) chlorine

OBJECTIVE #5: Know how to draw Ionic Dot Diagrams

Structures called Lewis Electron Dot Diagrams are used when illustrating a chemical bond between two or more atoms. Only the _____ electrons are used in chemical bonding, which is the _____ number of an atom's electron configuration.

Electron Lewis Dot Diagrams
(where "X" is a given element)

X

Li	Ca	Al
C	N	O
F	Ne	

Steps in drawing ionic dot diagrams

Step 1: Determine number of valence electrons each atom has and draw dot diagrams for each atom present

- Note: a subscript that *follows* the element symbol indicates the number of that atom
 - o ex: Li_2S has 2 lithium atoms and 1 sulfur atom

Step 2: Show the transfer of electrons from the metal atom(s) to non-metal atom(s)

- can only transfer to available bonding sites
 - o where there is not a pair of electrons already (●●)

Step 3: Show the resulting charged ions with appropriate charges and valence electrons

- the metal should always end up without any valence electrons and a _____ charge; the non-metal should always end up with an octet and a _____ charge

Examples:

NaCl	K_2O
MgO	MgCl_2



OBJECTIVE #6: Know how to Write and Name Ionic Compounds

A) Creating Ionic Formulas

- 1) Metal atom always comes first, non-metal atom goes second in a formula
- 2) Total positive charge on the metal atom must cancel total negative charge on the non-metal atom and the ionic compound must be neutral (charge of zero)
 - a. If more than one of an element is needed, a subscript *follows* that atom to indicate more than one

Ex) K_2O = 2 K atoms and 1 O atom

Ex) FeBr_2 = 1 Fe atom and 2 Br atoms

- 3) When using a polyatomic ion from Reference Table E, the charge that is used is only that which is in upper right hand corner of the group of bonded atoms

Ex) $\text{Cr}_2\text{O}_7^{-2}$ = the entire group of bonded atoms (Cr_2O_7) has an overall charge of -2

Ex) CN^- = both the C and N together (CN) have a charge of -1

- a. If more than one polyatomic ion is needed to allow the compound to be neutral, parentheses () must be placed around the polyatomic ion and the subscript follows outside the ()

Examples:

Ca^{+2} O^{-2}	Mg^{+2} NO_3^{-1}
Li^{+1} S^{-2}	Ni^{+2} OH^{-1}
Fe^{+2} P^{-3}	NH_4^{+1} Cl^{-1}

B) Naming Ionic Compounds

- 1) The metal comes first in the compound, and the name doesn't change at all
 - a. If the metal atom has more than one charge listed on the periodic table, however, a roman numeral must be used to indicate which charge is being used

I = +1	III = +3	V = +5	VII = +7
II = +2	IV = +4	VI = +6	

Ex) Fe can be Fe⁺² or Fe⁺³ Fe⁺² is called Iron II and Fe⁺³ is called Iron III

Ex) Au can be Au⁺¹ or Au⁺³ Au⁺¹ is called Gold I and Au⁺³ is called Gold III

- 2) The non-metal is second in the formula, and the name changes to have an -ide ending

Ex) oxygen = oxide nitrogen = nitride phosphorus = phosphide chlorine = chloride

- 3) If a polyatomic ion is second in the formula, the name is whatever it is on Reference table E

Examples:

MgCl ₂	
LiBr	
FeO	
Fe ₂ O ₃	
CuOH	
Ca(NO ₃) ₂	
NiSO ₄	

Table E
Selected Polyatomic Ions

Formula	Name	Formula	Name
H ₃ O ⁺	hydronium	CrO ₄ ²⁻	chromate
Hg ₂ ²⁺	mercury(I)	Cr ₂ O ₇ ²⁻	dichromate
NH ₄ ⁺	ammonium	MnO ₄ ⁻	permanganate
C ₂ H ₃ O ₂ ⁻	} acetate	NO ₂ ⁻	nitrite
CH ₃ COO ⁻		NO ₃ ⁻	nitrate
CN ⁻	cyanide	O ₂ ²⁻	peroxide
CO ₃ ²⁻	carbonate	OH ⁻	hydroxide
HCO ₃ ⁻	hydrogen carbonate	PO ₄ ³⁻	phosphate
C ₂ O ₄ ²⁻	oxalate	SCN ⁻	thiocyanate
ClO ⁻	hypochlorite	SO ₃ ²⁻	sulfite
ClO ₂ ⁻	chlorite	SO ₄ ²⁻	sulfate
ClO ₃ ⁻	chlorate	HSO ₄ ⁻	hydrogen sulfate
ClO ₄ ⁻	perchlorate	S ₂ O ₃ ²⁻	thiosulfate

C. Ionic Compound Formulas

- 1) The name of the metal comes first in the compound, and it will always have a positive charge
 - If a roman numeral is given, that is the positive charge to be used for the metal
 - o ex) Iron II is going to be Fe^{+2} and iron III is going to be Fe^{+3}
 - If there is no roman numeral given, you will need to look up the positive charge
 - o ex) Zinc will be Zn^{+2}
- 2) The non-metal will be second in the formula, with the name changed to have an -ide ending
 - look up the symbol and find the first negative charge of the non-metal element
 - ex) oxide (oxygen) will be O^{-2} and nitride (nitrogen) will be N^{-3}
- 3) If a polyatomic ion is second in the name, use the formula and negative charge that is on Reference table E
- 4) Total positive charge on the metal atom must cancel total negative charge on the non-metal atom and the ionic compound must be neutral (charge of zero)
 - o If more than one of an atom or group of atoms is needed, a subscript follows that atom (or polyatomic ion) to indicate more than one
 - o The subscripts MUST be in lowest terms

Examples:

Silver bromide	Copper I hydroxide
Iron III sulfide	Zinc carbide
Calcium nitrate	Cobalt III nitride

Naming and Formula Writing Practice

1. The correct name of the compound with the formula PbO_2 is
 - a) lead I oxide
 - b) lead II oxide
 - c) lead III oxide
 - d) lead IV oxide
2. The correct formula for the compound Cobalt III hydroxide is
 - a) CoH_3
 - b) Co_3OH
 - c) CoOH_3
 - d) $\text{Co}(\text{OH})_3$
3. The correct name for the formula NaClO_3 is sodium
 - a) chloride
 - b) chlorate
 - c) perchlorate
 - d) chlorite
4. The formula for potassium chlorite is
 - a) KCl
 - b) KClO
 - c) KClO_2
 - d) KClO_3

OBJECTIVE #7: Know the Types and Number of Covalent Bonds

Refresh:

Covalent Bonds are formed when 2 or more _____ atoms _____ valence electrons to achieve an octet

- duet (2 v.e.) for hydrogen

- A compound that has covalent bonding is called _____ substance

A) Two types of Covalent Bonds:

When two non-metals try and form a bond, they both are trying to _____ electrons to obtain an octet, so electronegativity (the attraction an atom has for its electrons) is used to determine what type of covalent bond will be formed

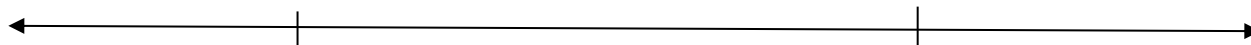
a) Nonpolar covalent bond: _____ sharing of valence electrons between two non-metals

ex) Br_2 , I_2 , N_2 , Cl_2 , H_2 , O_2 , F_2

b) Polar covalent bond: _____ sharing of valence electrons between two non-metals

ex) H_2O , NH_3 , CH_4 , SO_2 , CH_2Cl_2

Electronegativity Difference (END) Number Line



- The larger the END value, the more polar the bond and the greater the ionic character
- The smaller the END value, the more non-polar the bond and the greater the covalent character

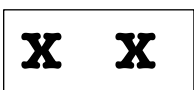
How to calculate bond polarity

HCl	NH_3	F_2	OCl_2	HF
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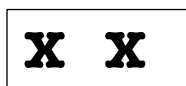
1. Which of the following bonds is the most polar bond in nature?
 a) Cl₂ b) HCl c) HBr d) HI
2. Which type of bond is formed between two atoms of chlorine?
 a) polar covalent b) nonpolar covalent c) metallic d) ionic
3. Which formula represents a molecule with a polar covalent bond?
 a) LiCl b) N₂ c) HCl d) KCl

B) Number of Covalent Bonds

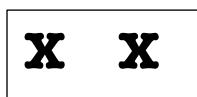
- a) Single covalent bonds: two non-metal atoms share _____ pair of valence electrons between them (2 v.e.)



- b) Double Covalent bonds: two non-metal atoms share _____ pairs of valence electrons between them (4 v.e.)



- c) Triple Covalent bonds: two non-metal atoms share _____ pairs of valence electrons between them (6 v.e.)



OBJECTIVE # 8: Know how to draw Covalent Dot Diagrams

1. Calculate the total number of valence electrons for the molecule by adding up the number of valence electrons for each atom.
2. Determine which atom is going to be the “central atom” – this is the non-metal atom furthest from an octet
 *Hydrogen can never be the central atom because it only needs one more electron to fill 1st energy level with two valence electrons (like Helium)
3. Distribute remaining atoms in the formula around the central atom. For every bond formed around the central atom, two valence electrons should be placed between them. (Remember that hydrogen can only make one single covalent bond.)
4. Distribute the remaining electrons as pairs to the central atom (or atoms), after subtracting the number of electrons already distributed from the total of valence electrons calculated in Step 1.
 *If there are fewer than 8 electrons on the central atom, this suggests a multiple bond is present
 - Two electrons fewer than 8 suggests a double bond
 - Four fewer than 8 suggests a triple bond or two double bonds.

Examples:

HBr	F ₂
CH ₄	H ₂ O
O ₂	CO ₂
NH ₃	N ₂

OBJECTIVE #9: Know the Shapes Molecular Substances (with covalent bonding)

There are four main shapes that covalent molecules can have, depending on the number and distribution of valence electrons around the central atom.

Linear	ex: HCl, F ₂ , HBr, I ₂ , CO ₂	Bent	ex: H ₂ O, SF ₂
Pyramidal	ex: NH ₃ , PF ₃	Tetrahedral	ex: CH ₄ , SiF ₄ , CF ₂ Br ₂

If the central atom is in:

Group 14		Group 15	Group 16	Group 17
X	X	X	X	X

Molecular Shape Questions:

1. Which molecule represents a tetrahedral molecule?

- a) Br₂ b) CH₄ c) CaCl₂ d) HBr

2. Which molecule represents a linear molecule?

- a) H₂O b) CO₂ c) NH₃ d) SH₂

3. Which molecule represents a pyramidal molecule?

- a) H₂O₂ b) PH₃ c) CF₄ d) Si₂

4. Which molecule represents a bent molecule?

- a) SiH₄ b) NH₃ c) SH₂ d) HBr

OBJECTIVE #10: Know how to Determine Molecular Polarity for Covalent Substances

The symmetry of a molecule is used to determine if the covalent molecule is polar or non-polar.

- This is different from bond polarity, where the electronegativity difference is used to determine if a covalent bond is polar or non-polar

a) Non-Polar Molecule = molecule is _____

- no dipoles within the molecule (or the dipoles cancel each other out)

ex) Br₂, CH₄, CO₂, SiF₄, H₂

b) Polar Molecule = molecule is _____

- has dipoles within the molecule

ex) NH₃, PCl₃, H₂O, H₂S, HF

Molecular Polarity Questions:

1. Which molecule is nonpolar?
a) H₂O b) NH₃ c) CO d) CO₂
2. Which molecule represents a polar molecule?
a) H₂S b) CH₄ c) CO₂ d) N₂
3. The shape and bonding in a diatomic fluorine molecule are best described as
a) symmetrical and polar c) symmetrical and nonpolar
b) asymmetrical and polar d) asymmetrical and nonpolar
4. Which statement explains why a molecule is nonpolar?
a) electrons are shared between the atoms
b) electrons are transferred between atoms
c) the distribution of charge in a molecule is symmetrical
d) the distribution of charge in the molecule is asymmetrical

OBJECTIVE #11: Know how to Write and Name Covalent Compounds

A) Covalent Compound Formulas

Writing formulas for covalent substances is very similar to writing formulas for ionic compounds.

- 1) The first non-metal atom in the compound is positively charged, and if a roman numeral is given, that tells you the charge of the ion.
- 2) If a polyatomic ion from Table E is given first, determine the formula and charge from the table
- 3) The charge of the second non-metal atom in the compound is negatively charged; look up the first negative charge on the periodic table.
- 4) If a polyatomic ion from Table E is given second, determine the formula and charge from the table
- 5) The total positive charge on the 1st non-metal atom must cancel total negative charge on the 2nd non-metal atom and the compound must be neutral (charge of zero)
 - a. If more than one of an atom or group of atoms is needed, a subscript follows that atom (or polyatomic ion) to indicate more than one

Carbon II oxide	Hydrogen sulfide
Sulfur VI oxide	Nitrogen V fluoride
Hydrogen carbonate	Ammonium chloride

B) Naming Covalent Compounds

- 1) For the 1st non-metal atom in the compound, the name doesn't change at all
 - a. however, a roman numeral must be used to indicate which charge is being used

I = +1	III = +3	V = +5	VII = +7
II = +2	IV = +4	VI = +6	

- 2) If a polyatomic ion is 1st in the formula, the name is whatever it is on Reference table E
- 3) For the 2nd non-metal in the formula, the name changes to have an -ide ending
 - ex) oxygen = oxide nitrogen = nitride phosphorus = phosphide chlorine = chloride
- 4) If a polyatomic ion is 2nd in the formula, the name is whatever it is on Reference table E

P ₂ O ₅	C(CO ₃) ₂
SO ₂	NH ₄ Cl
SO ₃	H ₃ PO ₄
NH ₃	NH ₄ OH

Naming and Formula Writing Practice

1. The correct name of the compound with the formula SF₄ is
 - a) sulfur fluoride
 - b) sulfur II fluoride
 - c) sulfur IV fluoride
 - d) sulfur VI fluoride
2. The correct formula for the compound ammonium sulfide is
 - a) NH₄S
 - b) NH₄SO₄
 - c) (NH₄)₂S
 - d) NH₄SO₃
3. The correct name for the formula P₄O₁₀ is
 - a) phosphorus oxide
 - b) phosphorus III oxide.
 - c) phosphorus IV oxide.
 - d) phosphorus V oxide
4. The formula for sulfur VI fluoride is
 - a) S₆F
 - b) SF₄
 - c) SF
 - d) SF₆

OBJECTIVE #12: Identify and Describe Intermolecular Forces

Intermolecular forces are attractions _____ molecular substances with covalent bonding

- They are _____ than chemical bonding (bonding between atoms)
- The type of intermolecular forces a molecular substance has determines the _____ it exists at room temperature [solid (s), liquid (l) or gas (g)]

A) London Dispersion Forces (Van der Waals)

- These attractions are found between all _____ molecules
 - o Molecules that are _____
 - o These substances are all in the _____ phase
 - The greater the mass, the more likely to be in the _____ phase

Examples:

B) Dipole – Dipole Attractions

- These attractions are found between all _____ molecules
 - o Molecules that are _____
 - o These substances are all in the _____ phase with _____ melting points

Examples:

Increasing strength



Increasing strength
↓

C) Hydrogen Bonds

- These attractions are found between _____ molecules and MUST have a hydrogen bonded to either a _____, _____ or _____ atom
 - o These substances are all in the _____ phase with _____ melting points

Examples:

Intermolecular Forces Questions:

1. In which molecule is hydrogen bonding the strongest?
a) HF b) HCl c) HBr d) HI
2. Which of the following compounds consists of dipole molecules?
a) H₂S b) CH₄ c) CO₂ d) N₂
3. Which intermolecular force of attraction accounts for the relatively high boiling point of water?
a) hydrogen bonding b) London Dispersion c) dipole-dipole d) covalent bonding
4. Which statement explains why H₂O has a higher boiling point than N₂?
a) H₂O has a greater mass than N₂ c) H₂O has stronger intermolecular forces than N₂
b) H₂O has less mass than N₂ d) H₂O has weaker intermolecular forces than N₂
5. Based in intermolecular forces, which of these substances would have the lowest boiling point?
a) He b) O₂ c) HCl d) NH₃
6. Based on the table below, state evidence that indicates HF has stronger intermolecular forces than CF₄.

Compound	Melting point (°C)	Boiling point (°C)	Solubility
CF ₄	-183.6	-127.8	insoluble
HF	-83.0	20.0	soluble