1. Characteristics of Ionic, Covalent, and Metallic Compounds

Property	Ionic	Covalent (Molecular)	Metallic
Formation	Metal + nonmetal	Two or more nonmetals	Metal atoms only
Electron behavior	Transferred from metal to nonmetal	Shared between atoms	"Sea of mobile electrons"
Melting/Boiling points	High	Low	Variable (generally high)
Electrical conductivity	When molten or dissolved (aq)	Do not conduct	Conduct heat and electricity
Physical properties	Hard, brittle crystalline solids	Exist as individual molecules	Malleable, ductile, shiny

2. Identifying Bond Type Using Electronegativity Difference

Let $\Delta EN = |EN_1 - EN_2|$.

ΔEN Range	Bond Type
0 to 0.4	Nonpolar covalent
0.5 to 1.7	Polar covalent
> 1.7	Ionic

General rule: metal + nonmetal $\Rightarrow$ ionic; nonmetal + nonmetal $\Rightarrow$ covalent.

3. Oxidation States of Common Groups

Group	Oxidation State
Group 1	+1
Group 2	+2
Group 13	+3
Group 15	–3
Group 16	–2
Group 17	–1

Special cases:

4. Covalent vs. Ionic Bonding Summary

Ionic Bonding

- Electrons transferred.
- Attraction between cations and anions.

Covalent Bonding

- Electrons shared.
- Bond order: single, double, triple.

5. Lewis Dot Structures (LDS)

Steps to draw:

1. Count all valence electrons.
2. Draw a skeleton (central atom is least electronegative, never H).

Element	Oxidation State
Hydrogen	+1 (usually), –1 in metal hydrides
Oxygen	–2, except in peroxides (–1)
Transition metals	Multiple oxidation states

3. Add single bonds.
4. Complete octets on outer atoms first.
5. Place remaining electrons on central atom.
6. Form double or triple bonds if needed to satisfy octet.

Octet rule exceptions:

- Incomplete octet: B, Be.
- Expanded octet: P, S, Cl, Br, Xe (period 3+).
- Odd-electron molecules (e.g., NO).

6. VSEPR Theory: Molecular Shapes

VSEPR formula: AX_mE_n (A = central atom, X = bonded atoms, E = lone pairs).

VSEPR Formula	Molecular Shape	Bond Angle
AX_2	Linear	180°
AX_3	Trigonal planar	120°
AX_2E	Bent	119°
AX_4	Tetrahedral	109.5°
AX_3E	Pyramidal	107°
AX_2E_2	Bent	105°
AX_5	Trigonal bipyramidal	–
AX_6	Octahedral	–

Chemical Formula	Central Atom	AX_mE_n	Why the Formula Order Is Written This Way
H_2O	O	AX_2E_2	H written first because it is less electronegative than O.
NH_3	N	AX_3E_1	H written after N due to naming convention; N is more common central atom.
CH_4	C	AX_4E_0	C is always central in organic compounds; H never central.
CO_2	C	AX_2E_0	By convention, C is written before O (less electronegative).
SO_2	S	AX_2E_1	S is less electronegative, so written before O.
HCN	C	AX_2E_0	Written H−C≡N; C is central but appears in the middle of the formula.
CH_3OH	C (O terminal)	AX_4E_0 (C); AX_2E_2 (O)	Formula follows organic grouping $(CH_3)(OH)$.
HNO_3	N	AX_3E_0 (approx.)	Acid formulas begin with H even though N is central.
H_2SO_4	S	AX_4E_0 (expanded)	Acids list H first; central atom (S) appears later.
OCl_2	O	AX_2E_2	O is less common as central; formula still writes O first due to electronegativity pattern.
ClO_2	Cl	AX_2E_2	Written ClO_2 because Cl is central despite being more electronegative than O.
PCl_3	P	AX_3E_1	P is central atom but formula follows naming order.

Table 1: Examples Showing Formula Order vs. VSEPR Central Atom

7. Naming Ionic, Covalent, Polyatomic, and Acid Compounds

Compound Type	Naming Rule	Example
Ionic	Metal name + nonmetal root + "ide"	NaCl = sodium chloride
Ionic (transition metal)	Metal name (Roman numeral) + nonmetal root + "ide"	$FeCl_3$ = iron(III) chloride
Polyatomic	Keep ion name intact	$NaNO_3$ = sodium nitrate
Covalent	Use prefixes: mono-, di-, tri-, tetra-, penta-, hexa-	CO_2 = carbon dioxide
Binary acid	"hydro" + root + "ic acid"	HCl(aq) = hydrochloric acid
Oxyacid (*ate*)	stem*ic* acid	HNO_3 = nitric acid
Oxyacid (*ite*)	stem*ous* acid	HNO_2 = nitrous acid

Note: Polyatomic ions: *ate* ending = more oxygen; *ite* ending = less oxygen.

8. Writing Formulas from Names

- Identify cation and anion.
- Balance charges to make the compound neutral.
- Place polyatomic ions in parentheses if more than one is needed: $Ca(OH)_2$.

9. Writing Names from Formulas

- Ionic: metal name + nonmetal ending in *ide*.
- Covalent: use prefixes.
- Polyatomic: keep ion name.
- Acids: follow acid naming rules.

Bonding and Naming Practice (Lewis Structures)

Problem 1. Ionic bonds are normally formed when:
A. electrons are shared between a metal and a nonmetal
B. electrons are shared between two nonmetals
C. electrons are transferred from a metal to a nonmetal
D. electrons are transferred from a nonmetal to a metal

Answer:

Correct: C
A metal transfers electrons to a nonmetal in ionic bonding.

Problem 2. Covalent bonds are normally formed when:
A. electrons are shared between a metal and a nonmetal
B. electrons are shared between two nonmetals
C. electrons are transferred from a metal to a nonmetal
D. electrons are transferred from a nonmetal to a metal

Answer:

Correct: B
Two nonmetals share electrons.

Problem 3. Which compound is ionic?
A. CO2 B. ZnCl2 C. SF2 D. SeBr2

Answer:

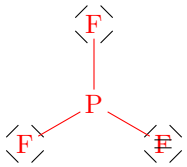
Correct: B
Zinc is a metal; chlorine is a nonmetal.

Problem 4. Which compound is covalent?
A. PF3 B. CNiBr3 C. GaCl3 D. CrO3

Answer:

Correct: A

Below is a Lewis structure for PF3 (trigonal pyramidal):



Problem 5. Which compound requires a Roman numeral?
A. SF6 B. AlBr3 C. ZnO D. PdCl2

Answer:

Correct: D
Palladium is a transition metal with variable oxidation states.

Problem 6. The correct formula for strontium phosphide is:
A. Sr3P B. SrPO4 C. Sr3P2 D. Sr3(PO4)2

Answer:

Correct: C
Sr is 2+ and P is 3-, producing Sr3P2.

Problem 7. The correct formula for aluminum sulfide is:
A. Al2S3 B. AlSO4 C. Al5S2 D. Al2(SO4)3

Answer:

Correct: A
Al is 3+ and S is 2-.

Problem 8. The correct formula for calcium hydroxide is:
A. CaO B. CaOH2 C. CaH2 D. Ca(OH)2

Answer:

Correct: D
Calcium (2+) requires two hydroxide ions.

Problem 9. The correct name for Na3N is:
A. sodium nitride
B. trisodium mononitride
C. sodium(III) nitride
D. sodium nitrate

Answer:

Correct: A
Standard ionic naming: sodium nitride.

Problem 10. The correct name for CaCl2 is:
A. calcium(II) chloride
B. calcium chloride
C. calcium dichloride
D. calcium chlorate

Answer:

Correct: B
Ca forms only Ca2+.

Problem 11. The correct formula for sodium carbonate is:
A. NaC B. Na2CO3 C. NaCO3 D. Na3CO3

Answer:

Correct: B
CO3 has a 2- charge, needing two Na+ ions.

Problem 12. The correct name for Mg(NO3)2 is:
A. magnesium nitride
B. magnesium nitrate
C. magnesium dinitrate
D. magnesium(II) nitrate

Answer:

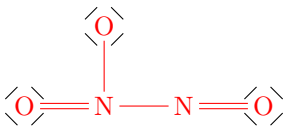
Correct: B
Nitrate is NO3-. Magnesium is always 2+.

Problem 13. The correct formula for dinitrogen trioxide is:
A. N2O B. N2O4 C. N2O3 D. N3O2

Answer:

Correct: C

Lewis structure for N_2O_3 (one simplified resonance form):



Problem 14. The correct name for SF4 is:
A. sulfur(IV) fluoride
B. sulfur fluoride(IV)
C. sulfur trifluoride
D. sulfur tetrafluoride

Answer:

Correct: D
SF4 uses covalent naming. Four fluorine atoms give the prefix "tetra."

Problem 15. Which of the following choices has classified the bonds correctly?

Answer:

Correct: D

H–O is covalent (nonmetal + nonmetal).
Ca–N is ionic (metal + nonmetal).

Problem 16. As a bond between a hydrogen atom and a sulfur atom is formed, electrons are:
A. Shared to form an ionic bond
B. Shared to form a covalent bond
C. Transferred to form an ionic bond
D. Transferred to form a covalent bond

Answer:

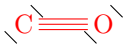
Correct: B
Hydrogen and sulfur are both nonmetals, forming covalent bonds by electron sharing.

Problem 17. Which of the following Lewis dot diagrams is correct?

Answer:

Correct: C

Below is a Lewis structure for CO showing the correct triple bond and lone pairs:



Note: Carbon monoxide has a triple bond between C and O, with a lone pair on each atom.

Problem 18. The molecular shape of BF3 is:
A. bent
B. pyramidal
C. tetrahedral
D. trigonal planar

Answer:

Correct: D
Boron has three bonds and zero lone pairs, giving trigonal planar shape.

Problem 19. The molecular shape of silicon dioxide (SiO2) is:
A. linear
B. pyramidal
C. bent
D. trigonal planar

Answer:

Correct: A

A representation of linear O=Si=O:

Problem 20. Given the Lewis structure O=O, what is the total number of electrons shared between the two oxygen atoms?
A. 1
B. 2
C. 3
D. 4

Answer:

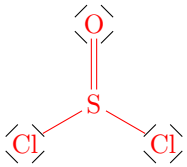
Correct: D
A double bond contains 4 shared electrons.

Problem 21. In the Lewis structure of SOCl2, which atom violates the octet rule?

Answer:

Correct: A (sulfur)

A sketch of SOCl2 structure:



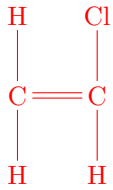
Sulfur has 10 electrons around it (expanded octet).

Problem 22. Which Lewis structure best represents C2H3Cl?

Answer:

Correct: B

Structure shows C=C double bond with three hydrogens and one chlorine:



Problem 23. Hexane (C6H14) and water do not form a solution. Which statement explains this phenomenon?
A. Hexane is polar and water is nonpolar.
B. Hexane is ionic and water is polar.
C. Hexane is nonpolar and water is polar.
D. Hexane is nonpolar and water is ionic.

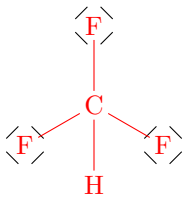
Answer:

Correct: C
Nonpolar substances do not dissolve in polar solvents ("like dissolves like").

Problem 24. Which of the Lewis structures below best represents the molecule CHF_3?

Answer:

Correct choice: A.
A correct Lewis structure for CHF_3 has carbon in the center with four single bonds (three to F, one to H). Each F has three lone pairs and H has none. A Lewis structure:



Problem 25. Electronegativity is defined as the tendency of an atom to
A. donate electrons to other atoms in a chemical bond
B. share electrons equally with other atoms
C. lose its valence electrons to become an ion
D. attract electrons toward itself in a chemical bond

Answer:

Correct choice: D.
Electronegativity measures how strongly an atom attracts the shared electrons in a bond.

Problem 26. Based on its location on the periodic table, which of the following elements should have the largest value for electronegativity?
A. lithium B. oxygen C. potassium D. selenium

Answer:

Correct choice: B (oxygen).
Electronegativity increases across a period and decreases down a group; among these options oxygen is closest to the top right of the table.

Problem 27. Which formula represents a nonpolar molecule containing polar covalent bonds?
A. H_2O B. CCl_4 C. NH_3 D. H_2

Answer:

Correct choice: B (CCl_4).
Each C–Cl bond is polar, but the tetrahedral geometry is perfectly symmetric, so the molecular dipoles cancel and the molecule is overall nonpolar.

Problem 28. Decide if each description represents **IONIC** bonding or **COVALENT** bonding.

Answer:

1. "It is a non conductor of electricity, whether it exists as a solid, melted, or dissolved in water."
   Covalent (molecular compounds do not conduct in any state).
2. "It is a nonelectrolyte in the solid form, but it can become a good conductor when melted or dissolved in water."
   Ionic (ions are free to move in the molten or aqueous state).
3. "The building blocks of this type of compound are called molecules."
   Covalent (molecules are made of covalently bonded atoms).
4. "The electrons are transferred from one element to another to form this type of bond."
   Ionic.
5. "The electrons are shared in between elements in this type of bond."
   Covalent.