Name _____ Class _____ Date _____

CHAPTER 3 | Chemical Compounds

SECTION 1

Ionic and Covalent Compounds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are ionic compounds?
- What are covalent compounds?

National Science Education Standards

PS 1a, 1b

What Are Ionic and Covalent Compounds?

Many things are made of combinations of elements called *compounds*. Sugar, salt, gasoline, and chalk are all compounds. They have atoms of more than one element joined together. How are the compounds alike and how are they different?

Scientists *classify*, or group, chemical compounds by the kinds of chemical bonds they have. A **chemical bond** joins atoms together to form compounds. The compounds are grouped by their bonding as either *ionic* or *covalent*.

Bonding happens between valence electrons of different atoms. *Valence electrons* are electrons in the outermost energy level of an atom. The type of compound that forms depends on what happens to the valence electrons. ☑

STUDY TIP

Work in Pairs Make flash cards with all of the vocabulary words in this section. Also make flash cards of the words in *italics* in this section.

On the other side of the card, write the definition of the word. Practice saying the words and their definitions.

READING CHECK

1. Identify What determines the type of compound that forms when atoms bond?

what happens to the valence electrons

What Makes a Compound Ionic?

An ionic bond is an attraction between ions that have opposite charges. Compounds that have ionic bonds are called **ionic compounds**.

Ionic compounds can be formed by the chemical reaction between a metal and a nonmetal. Metal atoms become positively charged ions when electrons move from the metal atoms to the nonmetal atoms. The nonmetal atoms become negatively charged ions. ☑

A sodium atom has lost an electron to a chlorine atom. The result is a positively charged sodium ion and a negatively charged chlorine ion. The attraction of the ions is called an ionic bond.

READING CHECK

2. Describe What kind of ions do metals form? What kind of ions do nonmetals form?

metals → cation (+)

nonmetals → anion (−)

What Are the Properties of an Ionic Compound?

Ionic compounds form strong bonds because of the attraction between oppositely charged ions. There are several properties that tell you a compound is ionic.

IONIC COMPOUNDS ARE BRITTLE

Ionic compounds tend to be brittle at room temperature. That means they break apart when hit. They break because their ions are arranged in a pattern that happens over and over again. The pattern is called a *crystal lattice*. Each ion in a lattice bonds to the ions around it that have the opposite charge. ☑

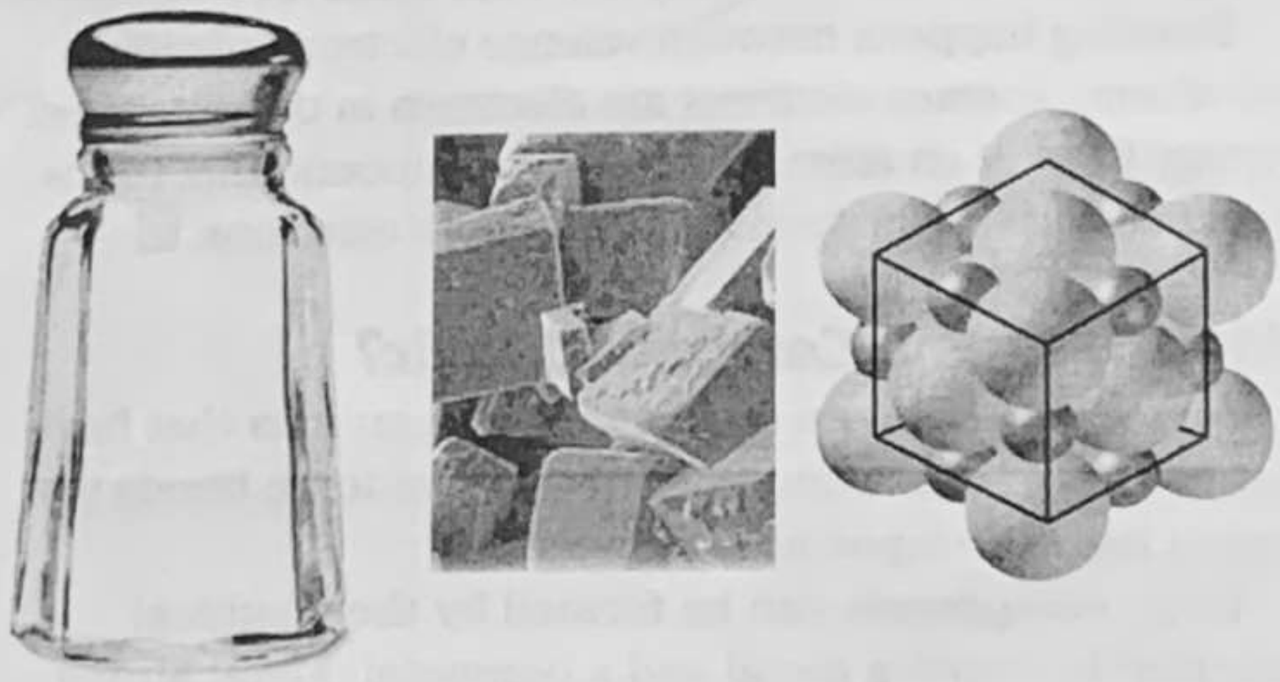
When you hit an ionic compound, the ions move and the pattern changes. Ions that have the same charge line up and repel each other. That makes the crystals break.

Sodium chloride crystals (shown below) all have a regular cubic shape. The shape is due to the way sodium and chloride ions are arranged in the crystal lattice.

READING CHECK

3. Describe What is a crystal lattice?

the shape that ionic compounds make due to attractive/ repulsive charges



Sodium chloride crystals all have a regular cubic shape because of the way sodium and chloride ions are arranged.

IONIC COMPOUNDS HAVE A HIGH MELTING POINT

Because of the strong bonds that hold ions together, ionic compounds don't melt easily. They have a high melting point. For example, sodium chloride must be heated to 801°C before it will melt. ☑

READING CHECK

4. Explain What causes ionic compounds to have high melting points?

the strong bonds that holds an ionic bond together

IONIC COMPOUNDS ARE SOLUBLE

Many ionic compounds are highly *soluble* in water. That means they dissolve easily in water. Water molecules attract each of the ions of an ionic compound and pull them away from each other.

IONIC COMPOUNDS CONDUCT ELECTRICITY

When an ionic compound dissolves in water, it forms a solution that can conduct an electric current. It conducts electricity because its ions are now free to move to complete an electric circuit. When ionic compounds are solids, their ions are not free to move. They will not conduct an electric current. ☑

*electrolytes

READING CHECK

5. Explain Why do ionic compounds dissolved in water conduct an electric current?

ions are free to move and complete a circuit

What Makes A Compound Covalent?

Many of the compounds in your body are covalent compounds. **Covalent compounds** form when atoms share electrons. The bond that forms when atoms share electrons is called a *covalent bond*. Atoms share electrons to fill their outermost energy level. This forms a group of atoms, each having a full valence shell.

The group of atoms that make up a covalent compound is called a *molecule*. A molecule is the smallest particle that you can divide a compound into and still have the same compound. For example, if you break water down further, it isn't water anymore. It is hydrogen and oxygen.

What Are the Properties of Covalent Compounds?

The properties of covalent compounds are very different from the properties of ionic compounds. This table lists the properties of covalent compounds.

Properties of Covalent Compounds

Property	Description
Solubility in water	Some covalent compounds do not dissolve in water. For example, oil does not dissolve in water. When mixed with water, the water molecules stay together and the oil molecules stay together.
Melting point	Normally, covalent compounds have lower melting and boiling points than ionic compounds. This is due to weaker forces of attraction in a covalent compound than in an ionic compound.
Electrical conductivity	Most covalent compounds do not conduct electricity when dissolved in water. This is because most covalent compounds that dissolve in water form solutions that do not have ions.

are not soluble

low melting point

does not conduct

STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

6. Identify Give three ways covalent compounds often differ from ionic compounds.

Solubility, melting point, conductivity

Name _____ Class _____ Date _____

Section 1 Review

NSES PS 1a, 1b

SECTION VOCABULARY

chemical bond an interaction that holds atoms or ions together **covalent compound** a chemical compound that is formed by the sharing of electrons	**ionic compound** a compound made of oppositely charged ions

1. **Compare** How does the melting point of ionic compounds compare to that of covalent compounds?

Ionic compounds have higher melting

2. **Make Inferences** Examine the table below. Use the information in the table to help you decide if the compound is ionic or covalent. Write *ionic* or *covalent* in the box next to each compound.

Compound	Property	Ionic or covalent
A	low melting point	C
B	smallest particle is a molecule	C
C	water solution conducts an electric current	I
D	high melting point	I

3. **Describe** Why do ionic compounds tend to be brittle?

ions shift and break due to repulsive forces

4. **Explain** Solid crystals of ionic compounds do not conduct an electric current. Why does the solution conduct electricity when the crystals dissolve in water?

ions are free to move to complete a circuit

5. **Describe** Describe how a metal and a nonmetal can combine by forming an ionic bond.

transfer of electrons from metal to non metal

Chemical Bonding

Ionic Bond	**between a Metal and Non-Metal**	**(M + NM)**
Covalent Bond	**between a Non-Metal and Non-Metal**	**(NM + NM)**
Metallic Bond	**between a Metal and Metal**	**(M+ M)**

Determine if the elements in the following compounds are metals or non-metals. Describe the type of bonding that occurs in the compound.

Compound	Element 1 (metal or non-metal?)	Element 2 (metal or non-metal?)	Bond Type
NO_2	N = non-metal	O = non-metal	covalent
NaCl	M	NM	I
SO_2	NM	NM	C
PO_4^{3-}	NM	NM	C
$MgBr_2$	M	NM	I
CaO	M	NM	I
H_2O	NM	NM	C
K_2O	M	NM	I
Cu-Zn alloy	M	M	M
O_2	NM	NM	C
$CuCl_2$	M	NM	I
NO_2^-	NM	NM	C
TiO_2	M	NM	I
HF	NM	NM	C
Rb_2S	M	NM	I
Au-Ag mixture	M	M	M
Fe_2O_3	M	NM	I
$C_6H_{12}O_{22}$	NM	NM	C

Naming Molecular Compounds

How are the chemical formula and name of a molecular compound related?

Why?

When you began chemistry class this year, you probably already knew that the chemical formula for carbon dioxide was CO_2. Today you will find out why CO_2 is named that way. Naming chemical compounds correctly is of paramount importance. The slight difference between the names carbon monoxide (CO, a poisonous, deadly gas) and carbon dioxide (CO_2, a greenhouse gas that we exhale when we breathe out) can be the difference between life and death! In this activity you will learn the naming system for molecular compounds.

Model 1 – Molecular Compounds

Molecular Formula	Number of Atoms of First Element	Number of Atoms of Second Element	Name of Compound
ClF	1	1	Chlorine monofluoride
ClF_5	1	5	Chlorine pentafluoride
CO	1	1	Carbon monoxide
CO_2	1	2	Carbon dioxide
Cl_2O	2	1	Dichlorine monoxide
PCl_5	1	5	Phosphorus pentachlroride
N_2O_5	2	5	Dinitrogen pentoxide

1. Fill in the table to indicate the number of atoms of each type in the molecular formula.
2. Examine the molecular formulas given in Model 1 for various molecular compounds.
   a. How many different *elements* are present in each compound shown?

   2

   b. Do the compounds combine metals with metals, metals with nonmetals, or nonmetals with nonmetals?

   nm w/ nm

   c. Based on your answer to *b*, what type of bonding must be involved in molecular compounds?

   covalent
3. Find all of the compounds in Model 1 that have chlorine and fluorine in them. Explain why the name "chlorine fluoride" is not sufficient to identify a specific compound.

   we would not be able to tell the difference between them
4. Assuming that the name of the compound gives a clue to its molecular formula, predict how many atoms each of these prefixes indicates, and provide two examples.

   mono- 1

   di- 2

   penta- 5

Model 2 – Prefixes and Suffixes

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

Molecular Formula	Name of Compound
BCl_3	Boron trichloride
SF_6	Sulfur hexafluoride
IF_7	Iodine heptafluoride
NI_3	Nitrogen triiodide
N_2O_4	Dinitrogen tetroxide
Cl_2O	Dichlorine monoxide
P_4O_{10}	Tetraphosphorus decoxide
B_5H_9	Pentaboron nonahydride
Br_3O_8	Tribromine octoxide
ClF	Chlorine monofluoride

5. Examine the prefixes in Model 2. Fill in the numerical value that corresponds to each prefix.

6. What suffix (ending) do all the compound names in Model 2 have in common?

-ide

7. Carefully examine the names of the compounds in Model 2. When is a prefix NOT used in front of the name of an element?

first element, with just one

8. Consider the compound NO.

   a. Which element, nitrogen or oxygen, would require a prefix in the molecule name? Explain your answer.

oxygen, second element

   b. Name the molecule NO.

nitrogen monoxide

9. Find two compounds in Model 2 that contain a subscript of "4" in their molecular formula.

   a. List the formulas and names for the two compounds.

N_2O_4 → dinitrogen tetroxide , P_4O_{10} tetraphosphorus decoxide

   b. What is different about the spelling of the prefix meaning "four" in these two names?

tetr vs tetra

4

10. Find two compounds in Model 2 that contain the prefix "mono-" in their names.

a. List the formulas and names for the two compounds.

Cl_2O → dichlorine monoxide
ClF → chlorine monofluoride

b. What is different about the spelling of the prefix meaning "one" in these two names?

mon vs mono

11. Identify any remaining names of compounds in Model 2 where the prefixes that do not exactly match the spelling shown in the prefix table.

dera vs dec , oct vs octa

12. Use your answers to Questions 9–11 to write a guideline for how and when to modify a prefix name for a molecular compound. Come to a consensus within your group.

when the element is oxygen and the prefix ends with an o or a

13. Would the guideline you wrote for Question 12 give you the correct name for NI_3 as it is given in Model 2? If not, modify your guideline to include this example.

14. All of the compounds listed in Model 2 are binary molecular compounds. Compounds such as CH_3OH or PF_2Cl_3 are not binary, and compounds such as NaCl or $CaCl_2$ are not molecular. Propose a definition for "binary molecular compounds."

two elements, two nonmetals

15. Collaborate with your group members to write a list of rules for recognizing and naming binary molecular compounds from their chemical formulas.

16. For each of the following compounds, indicate whether or not your naming rules from Question 15 will apply. If not, explain why the naming rules do not apply.

FeI_3 — NO → ionic

ICl_5 — yes

$HBrO_4$ — NO → Ionic

17. Using the rules your group developed in Question 15, name each of the following molecular compounds.

Molecular Formula	Molecule Name
PBr_3	phosphorus tribromide
SCl_4	sulfur tetrachloride
N_2F_2	dinitrogen difluoride
SO_3	sulfur trioxide
BrF	bromine monofluoride

18. Write molecular formulas for the following compounds.

Molecular Formula	Molecule Name
S_2F_{10}	Disulfur decafluoride
CCl_4	Carbon tetrachloride
OF_2	Oxygen difluoride
N_2O_3	Dinitrogen trioxide
P_4S_7	Tetraphosphorus heptasulfide

STOP

Covalent Compounds

CO2 1. carbon dioxide

N2O5 2. dinitrogen pentoxide

P2O5 3. diphosphorus pentoxide

N2O 4. dinitrogen monoxide

N2O4 5. dinitrogen tetroxide

PO5 6. phosphorus pentoxide

CCl4 7. carbon tetrachloride

8. P_4O_{10} tetraphosphorus decoxide

9. S_2O_3 disulfur trioxide

10. CS_2 carbon disulfide

11. SO_2 sulfur dioxide

12. BF_3 Boron trifluoride

13. PO_2 phosphorus dioxide

14. $SiCl_4$ Silicon tetrachloride

C. NmNm

1) Name of 1st element (with prefix if more than one atom)
2) prefix for number of atoms- root of nonmetal name –ide ending

mon(o)- 1	tri- 3	penta-5	hepta-7	nona-9
di- 2	tetra- 4	hex(a)- 6	octa-8	deca-10

ex. N_2O dinitrogen monoxide; NO_2 nitrogen dioxide

Name the following:

1. SO_3 sulfur trioxide
2. $AsCl_3$ arsenic trichloride
3. N_2O_3 dinitrogen trioxide
4. P_2O_5 diphosphorus pentoxide
5. $GeCl_4$ germanium tetrachloride
6. XeF_6 xenon hexafluoride
7. SF_4 sulfur tetrafluoride
8. NO_3 nitrogen trioxide
9. SiO_2 silicon dioxide
10. CO carbon monoxide

Write formulas for the following:

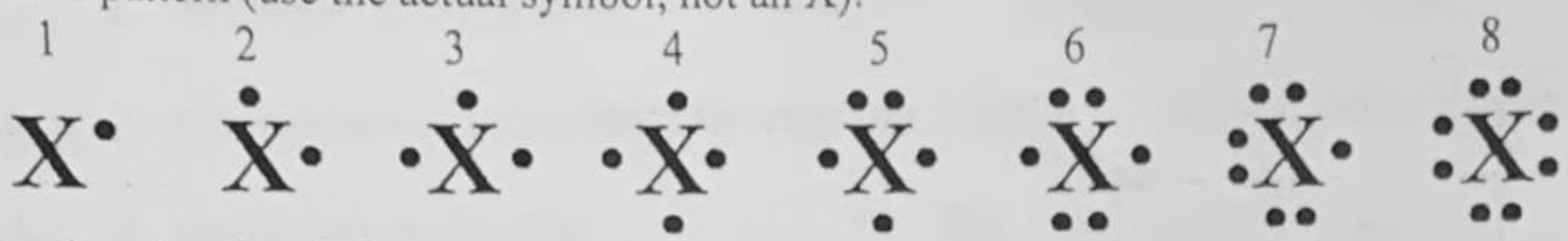
11. Sulfur dioxide SO_2
12. Phosphorous trichloride PCl_3
13. Nitrogen monoxide NO
14. Carbon tetraflouride CF_4
15. Dinitrogen pentoxide N_2O_5
16. Sulfur trioxide SO_3
17. Carbon monoxide CO
18. Phosphorous pentachloride PCl_5
19. Arsenic tribromide $AsBr_3$
20. Nitrogen triiodide NI_3

Name:_____

Lewis Dot Structures for Atoms

Date:_____ Period:_____

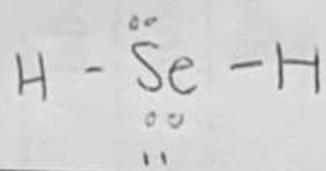
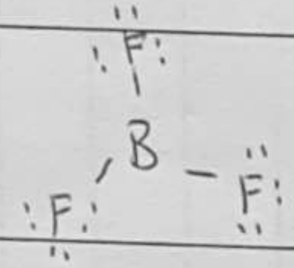
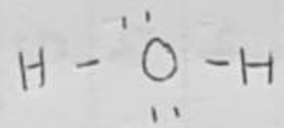
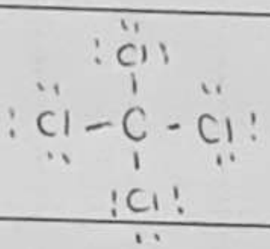
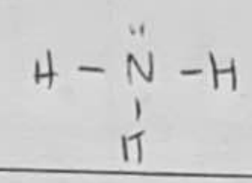
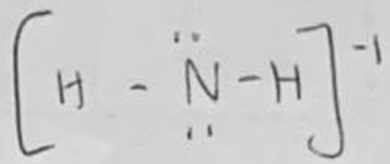
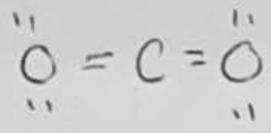
In a Lewis dot structure of an atom, dots are placed around the symbol of the atom. The number of dots is equal to the number of valence electrons. One dot is placed on each side before doubling up.
General pattern (use the actual symbol, not an X):



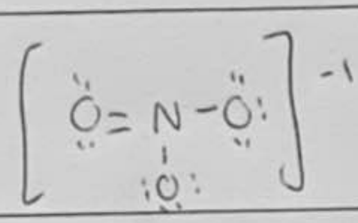
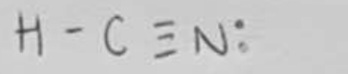
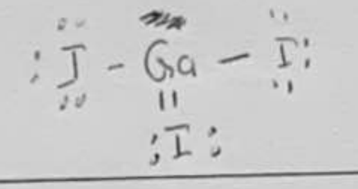
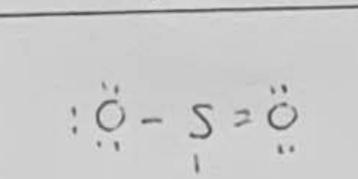
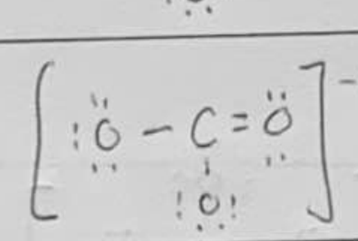
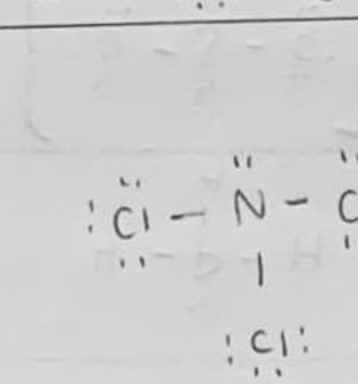
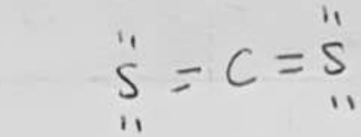
Complete the chart below:

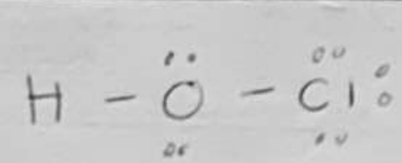
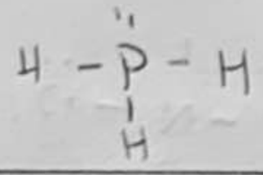
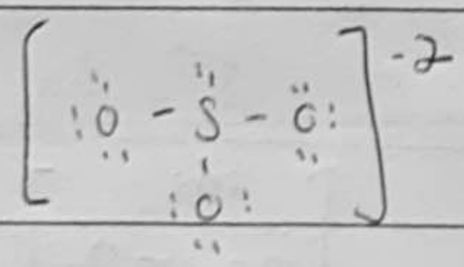
Element	# of Valence Electrons	Lewis Dot Structure
Hydrogen (H)	1	H•
Lithium (Li)	1	Li•
Sodium (Na)	1	Na•
Potassium (K)	1	K•
Beryllium (Be)	2	•Be•
Magnesium (Mg)	2	•Mg•
Calcium (Ca)	2	•Ca•
Boron (B)	3	•B•
Aluminum (Al)	3	•Al•
Carbon (C)	4	•C•
Silicon (Si)	4	•Si•
Nitrogen (N)	5	•N:
Phosphorus (P)	5	•P:
Fluorine (F)	7	:F:
Chlorine (Cl)	7	:Cl:
Bromine (Br)	7	:Br:
Helium (He)	2	•He•
Neon (Ne)	8	:Ne:

Lewis Structures Classwork

	Molecule	Lewis Structure	Bonded Atoms	Lone Pairs	Shape	P/NP
1.	SeH_2 6 + (1×2) = 8ve⁻		2	2	Bent	P
2.	BF_3 3 + (7×3) = 24ve⁻		3	0	trigonal planar	NP
3.	H_2O (1×2) + 6 = 8ve⁻		2	2	Bent	P
4.	CCl_4 4 + (7×4) = 32ve⁻		4	0	tetrahedral	NP
5.	NH_3 5 + (1×3) = 8ve⁻		3	1	trigonal pyramidal	P
7.	NH_2^{1-} 5 + (1×2) + 1 = 8ve⁻		2	2	Bent	P
8.	CO_2 4 + (6×2) = 16ve⁻		2	0	linear	NP

16

	Molecule	Lewis Structure	Bonded Atoms	Lone Pairs	Shape	P/NP
9.	NO_3^{1-} 5+(6x3)+1 24ve⁻		3	0	trigonal planar	NP
10.	HCN 1+4+5 10ve⁻		2	0	linear	P
11.	GaI_3 3+(7x3) =24ve⁻		3	0	trigonal planar	NP
12.	SO_3 6+(6x3) =24ve⁻		3	0	trigonal planar	NP
13.	CO_3^{2-} 4+(6x3)+2 24ve⁻		3	0	trigonal planar	NP
14.	NCl_3 5+(7x3) =26ve⁻		3	1	trigonal pyramidal	P
15.	CS_2 4+(6x2) =16ve⁻		2	0	linear	NP

	Molecule	Lewis Structure	Bonded Atoms	Lone Pairs	Shape	P/NP
16.	HOCl 1 1 1 1+6+7 = 14ve⁻		2	2	Bent	P
17.	PH_3 1 1 5+(3x1) = 8ve⁻		3	1	trigonal pyramidal	P
19.	SO_3^{2-} 1 1 6+(6x3)+2 26ve⁻		3	1	trigonal pyramidal	P