

**2014 AP<sup>®</sup> CHEMISTRY FREE-RESPONSE QUESTIONS**

Nonmetal	C	N	O	Ne	Si	P	S	Ar
Formula of Compound	CF <sub>4</sub>	NF <sub>3</sub>	OF <sub>2</sub>	No compound	SiF <sub>4</sub>	PF <sub>3</sub>	SF <sub>2</sub>	No compound

5. Some binary compounds that form between fluorine and various nonmetals are listed in the table above. A student examines the data in the table and poses the following hypothesis: the number of F atoms that will bond to a nonmetal is always equal to 8 minus the number of valence electrons in the nonmetal atom.

- (a) Based on the student's hypothesis, what should be the formula of the compound that forms between chlorine and fluorine?
- (b) In an attempt to verify the hypothesis, the student researches the fluoride compounds of the other halogens and finds the formula ClF<sub>3</sub>. In the box below, draw a complete Lewis electron-dot diagram for a molecule of ClF<sub>3</sub>.

- (c) Two possible geometric shapes for the ClF<sub>3</sub> molecule are trigonal planar and T-shaped. The student does some research and learns that the molecule has a dipole moment. Which of the two shapes is consistent with the fact that the ClF<sub>3</sub> molecule has a dipole moment? Justify your answer in terms of bond polarity and molecular structure.

In an attempt to resolve the existence of the ClF<sub>3</sub> molecule with the hypothesis stated above, the student researches the compounds that form between halogens and fluorine, and assembles the following list.

Halogen	Formula(s)
F	F <sub>2</sub>
Cl	
Br	BrF, BrF <sub>3</sub> , BrF <sub>5</sub>
I	IF, IF <sub>3</sub> , IF <sub>5</sub> , IF <sub>7</sub>

- (d) Based on concepts of atomic structure and periodicity, propose a modification to the student's previous hypothesis to account for the compounds that form between halogens and fluorine.

**AP<sup>®</sup> CHEMISTRY  
2014 SCORING GUIDELINES**

**Question 5  
(4 points)**

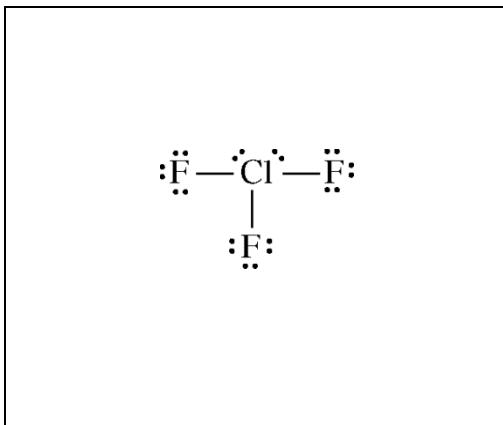
Nonmetal	C	N	O	Ne	Si	P	S	Ar
Formula of Compound	CF <sub>4</sub>	NF <sub>3</sub>	OF <sub>2</sub>	No compound	SiF <sub>4</sub>	PF <sub>3</sub>	SF <sub>2</sub>	No compound

Some binary compounds that form between fluorine and various nonmetals are listed in the table above. A student examines the data in the table and poses the following hypothesis: the number of F atoms that will bond to a nonmetal is always equal to 8 minus the number of valence electrons in the nonmetal atom.

- (a) Based on the student's hypothesis, what should be the formula of the compound that forms between chlorine and fluorine?

ClF	1 point is earned for the correct formula.
-----	--

- (b) In an attempt to verify the hypothesis, the student researches the fluoride compounds of the other halogens and finds the formula ClF<sub>3</sub>. In the box below, draw a complete Lewis electron-dot diagram for a molecule of ClF<sub>3</sub>.



See diagram above.	1 point is earned for a central Cl atom surrounded by three bonding pairs with F atoms and two nonbonding (lone) pairs of electrons. F atoms must have three nonbonding pairs each. Electron pairs can be depicted as dots or line segments.
--------------------	--

**AP<sup>®</sup> CHEMISTRY  
2014 SCORING GUIDELINES**

**Question 5 (continued)**

- (c) Two possible geometric shapes for the  $\text{ClF}_3$  molecule are trigonal planar and T-shaped. The student does some research and learns that the molecule has a dipole moment. Which of the two shapes is consistent with the fact that the  $\text{ClF}_3$  molecule has a dipole moment? Justify your answer in terms of bond polarity and molecular structure.

<p>The molecule is T-shaped because a T-shaped structure is asymmetric with dipoles that do not cancel out, but produce a net dipole (i.e., a polar molecule). OR because, if the molecule had a trigonal planar structure, the molecule would be symmetric with dipoles that cancel out and produce a net dipole of zero (i.e., a nonpolar molecule), which is not consistent with the observation that the <math>\text{ClF}_3</math> molecule does have a dipole moment.</p>	1 point is earned for indicating that the molecule is T-shaped with an acceptable explanation.
--	--

In an attempt to resolve the existence of the  $\text{ClF}_3$  molecule with the hypothesis stated above, the student researches the compounds that form between halogens and fluorine, and assembles the following list.

Halogen	Formula(s)
F	$\text{F}_2$
Cl	
Br	$\text{BrF}$ , $\text{BrF}_3$ , $\text{BrF}_5$
I	$\text{IF}$ , $\text{IF}_3$ , $\text{IF}_5$ , $\text{IF}_7$

- (d) Based on concepts of atomic structure and periodicity, propose a modification to the student's previous hypothesis to account for the compounds that form between halogens and fluorine.

<p>An acceptable hypothesis (descriptive or formulaic) must include the following ideas:</p> <ol style="list-style-type: none"><li>1. Atomic Structure: e.g., odd number of F atoms</li><li>2. Periodicity: e.g., as the atomic number of the central halogen atom increases, the number of F atoms increases.</li></ol>	1 point is earned for an acceptably modified hypothesis that addresses both atomic structure and periodicity.
--	---