

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

**Question 5**  
**(4 points)**

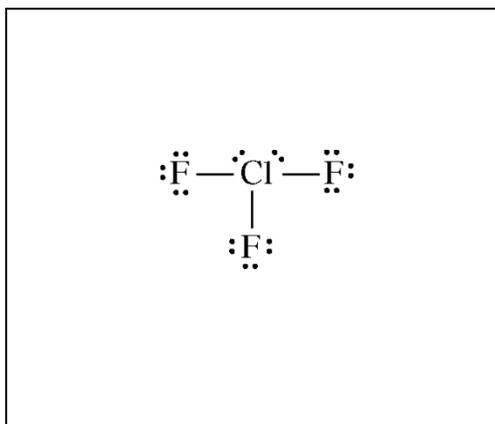
Nonmetal	C	N	O	Ne	Si	P	S	Ar
Formula of Compound	CF <sub>4</sub>	NF <sub>3</sub>	OF <sub>2</sub>	No compound	SiF <sub>4</sub>	PF <sub>3</sub>	SF <sub>2</sub>	No compound

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.
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- (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.
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**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</p> <p>because a T-shaped structure is asymmetric with dipoles that do not cancel out, but produce a net dipole (i.e., a polar molecule).</p> <p>OR</p> <p>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>	<p>1 point is earned for indicating that the molecule is T-shaped with an acceptable explanation.</p>
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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.

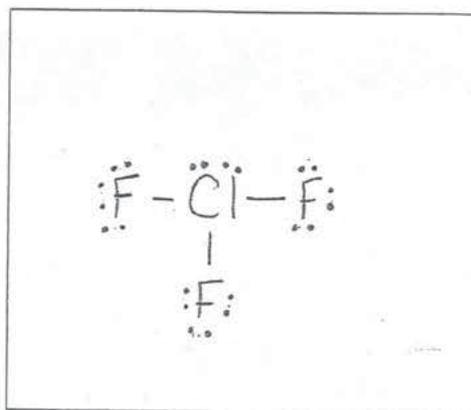
<p>An acceptable hypothesis (descriptive or formulaic) must include the following ideas:</p> <ol style="list-style-type: none"><li>1. Atomic Structure: e.g., odd number of F atoms</li><li>2. Periodicity: e.g., as the atomic number of the central halogen atom increases, the number of F atoms increases.</li></ol>	<p>1 point is earned for an acceptably modified hypothesis that addresses both atomic structure and periodicity.</p>
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5A,

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>.

$$7 + 7(3) = 28 \text{ electrons}$$



- (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.

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(a) Chlorine has seven valence electrons.

$$8 - 7 = 1$$

That means only one Fluorine will bond with chlorine.



(c)  $\text{ClF}_3$  has to be T-shaped because the two pairs of lone electrons on the top create the dipole moment. The lone pair makes the angles of the bonds smaller and creates a larger electron force on the molecule in that area. It's T-shaped because the 3 bonded domains are made into a "T" like shape. If it were trigonal planar, the molecule wouldn't have the two unbonded domains on top.

(d) The number of F atoms will equal 8 minus the number of valence electrons. In addition to that as you go down the group, you bond the element with the previous numbers of F atoms and also use the formula  $\text{XF}_{8-n+2}$ . As you go down a group the formulas increase by 1.

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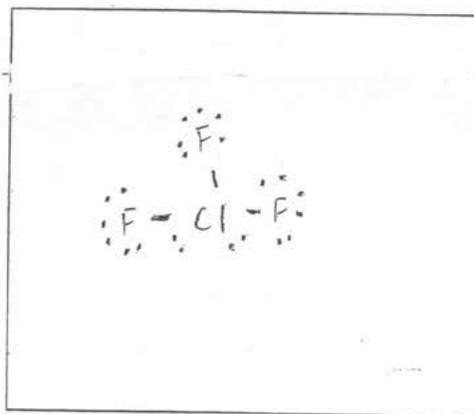
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5. Some binary compounds that form between fluorine and various nonmetals are listed in the table above. A student examines the data in the table and poses the following hypothesis: the number of F atoms that will bond to a nonmetal is always equal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

7 21  
Cl F<sub>3</sub>

28



- (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>
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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.

(A) - ClF would be the compound

(B) -

(C) - T-shaped is consistent because the dipole moment would cause the molecules to pull towards each other causing the molecular structure to appear T-shaped

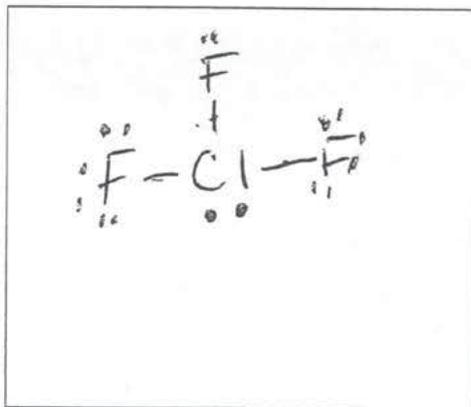
(D) - Perhaps change the rule to halogens and fluorine bend at odd intervals increasing by 1 interval each orbital. F can have 1 Cl 3 Br 5 I 7

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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	ClF, ClF <sub>3</sub> , ClF <sub>5</sub>
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.

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5C<sub>2</sub>

A.) ClF  
~~B.)~~

C. T-Shape because ~~dipole~~ bonds are ~~for~~ polar and the lone pair molecular ~~structural~~ structure shows that.

D.) The # of F atoms that bond to nonmetal always equal the number of F electron minus ~~odd~~ <sup>Even</sup> numbers until the halogen runs out.

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

**Question 5**

**Overview**

This question was designed to explore student understanding of atomic and molecular structures, with specific reference to periodic trends that are reflective of the periodicity of electronic structure and molecular geometry using Lewis diagrams and the VSEPR model.

**Sample: 5A**

**Score: 4**

This response earned all 4 points: 1 point in part (a), 1 point in part (b), 1 point in part (c), and 1 point in part (d).

**Sample: 5B**

**Score: 3**

The points were earned in parts (a) and (b). The student did not earn the point in part (c) because the response does not explain why there is a dipole moment. The student earned a point in part (d) by including something about atomic structure and something about periodicity.

**Sample: 5C**

**Score: 1**

The point was earned in part (a). The point was not earned in part (b) because the Cl atom is missing one of the lone pairs of electrons and one of the F atoms is missing two lone pairs. The point was not earned in part (c) because the response does not explain why there is a dipole moment. The student did not earn the point in part (d) because the proposed hypothesis is not based on atomic structure and periodicity.