

**Question 1:**

Intermolecular forces can hold molecules to each other. The hydrogen bond is a type of intermolecular force that acts between the molecules of certain compounds. When a hydrogen atom of a molecule is bonded to a more electronegative atom such as nitrogen, oxygen, or fluorine, both atoms obtain partial charges as a result of the polarity of the bond. Because of this charge distribution, a bond is developed between the positive hydrogen of one molecule and the negative atom of another. The melting and boiling points of a particular compound depend on the strength of its intermolecular forces. For compounds with stronger intermolecular forces, more energy is required to break the intermolecular bonds.

In a laboratory, students are given a colorless liquid organic compound and are asked to identify it. The students perform certain tests and identify the chemical formula of the compound as  $C_4H_8O_2$ , but they disagree on its structural formula.

*Student 1*

The compound is butyric acid. The following model shows the structure of butyric acid.

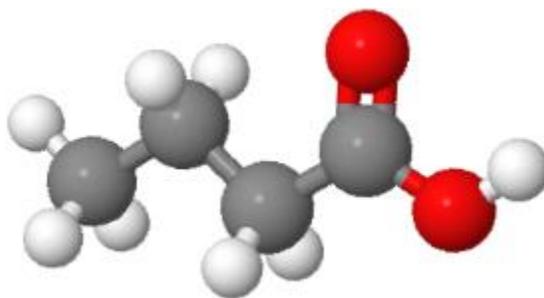


Figure 1

*Student 2*

The compound is ethyl acetate. The following model shows the structure of ethyl acetate.

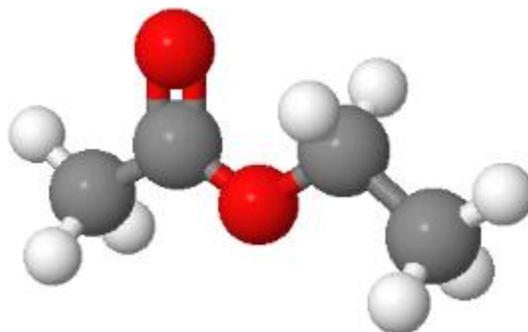


Figure 2

**Question 1.** Figure 3 shows the structure of the carboxyl functional group, and Figure 4 shows the structure of the alcohol functional group.

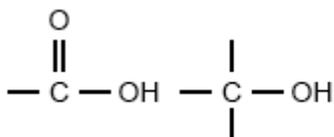


Figure 3

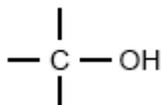


Figure 4

Which of the following statements about the unknown compound is true?

- A. Student 2 identifies that the unknown compound has an alcohol group.
  - B. Student 2 identifies that the unknown compound has a carboxyl group.
  - C. Student 1 identifies that the unknown compound has a carboxyl group.
  - D. Student 1 identifies that the unknown compound has an alcohol group.
- 

### *Questions 2-4:*

Group 17 of the periodic table contains elements called halogens, including fluorine, chlorine, bromine, iodine, and astatine. Each of these elements has seven electrons in its outermost shell. Elements toward the bottom of this group have greater atomic weight than those at the top and are less reactive.

Fluorine and chlorine are gases, bromine is a liquid, and iodine is a solid at room temperature. The elements also show a trend in their coloration—their color becomes darker down the group. Fluorine is pale yellow, chlorine is yellow-green, bromine is red-brown, and iodine is purple. Toxicity can also vary within the halogen group. Fluorine and chlorine are highly toxic. Bromine and iodine are also toxic, but less so than fluorine and chlorine.

Astatine (At), present near the bottom of the group, in period 6, is a radioactive element with an atomic number of 85. The most stable isotope of At has a half-life of approximately 8.1 hours. Because of its short half-life and rare occurrence, the properties of astatine are not well known. Scientists experience much difficulty studying the properties of astatine because it decays rapidly. Because of this, scientists differ as to whether the element should be classified as a metal or as a nonmetal.

#### *Scientist 1*

Like the other halogens, astatine has seven electrons in its outermost shell. As a result, it can be expected to have similar chemical properties to the other halogens, which are all nonmetals. Therefore, astatine should be classified as a nonmetal.

#### *Scientist 2*

Although groups 15 and 16 of the periodic table have nonmetals at the top, they have metals at the bottom. Because of astatine's high atomic weight and its many electron shells, it can be expected to have similar properties to the elements at the bottom of groups 15 and 16. Therefore, astatine should be classified as a metal.

**Question 2.** What would the scientists' prediction about astatine's state of matter most likely be?

- A. Scientist 1 would predict that astatine is a liquid, while Scientist 2 would predict that astatine is a solid at standard temperature and pressure.
  - B. Both scientists would predict that astatine is a solid at standard temperature and pressure.
  - C. Both scientists would predict that astatine is a liquid at standard temperature and pressure.
  - D. Scientist 1 would predict that astatine is a solid, while Scientist 2 would predict that astatine is a liquid at standard temperature and pressure.
- 

**Question 3.** Experiments have not conclusively shown whether astatine forms diatomic molecules. If  $\text{At}_2$  were to be discovered, whose viewpoint would this best support and why?

- A. Scientist 2; the rest of the elements in period 6 form diatomic molecules.
  - B. Scientist 1; nonmetals can be present in the diatomic form.
  - C. Scientist 2; metals can be present in the diatomic form.
  - D. Scientist 1; the rest of the elements in group 17 form diatomic molecules.
- 

**Question 4.** If astatine is found to be a poor conductor of heat, whose viewpoint would that finding most likely support?

- A. Neither Scientist 1 nor Scientist 2
  - B. Scientist 1 only
  - C. Both Scientist 1 and Scientist 2
  - D. Scientist 2 only
-

**Questions 5-7:**

Nitrogen pentafluoride ( $\text{NF}_5$ ) is a theoretical compound made of nitrogen and fluorine. This compound has not been definitively isolated or produced in the laboratory. Three scientists expressed their views about the existence and appearance of nitrogen pentafluoride.

*Scientist 1*

$\text{NF}_5$  exists as a trigonal bipyramidal molecule.  $\text{NF}_5$  is covalently bonded and would be a gas under standard conditions. Figure 1 shows the structure of  $\text{NF}_5$  as a trigonal bipyramidal molecule.

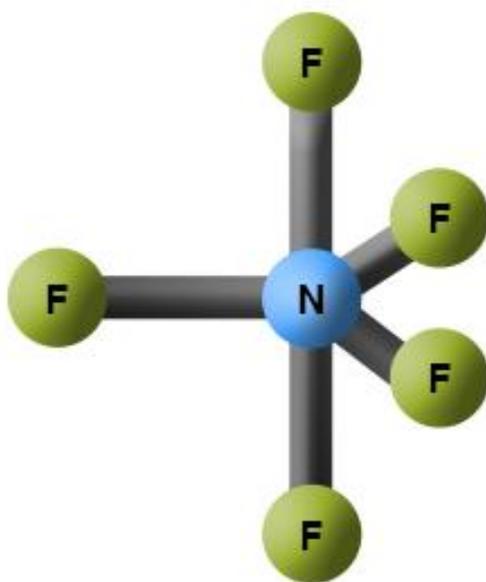


Figure 1

*Scientist 2*

Nitrogen pentafluoride exists in the ionic form  $\text{NF}_4^+\text{F}^-$ . It would be in the form of a crystalline solid. Figure 2 shows the structure of  $\text{NF}_4^+\text{F}^-$ .

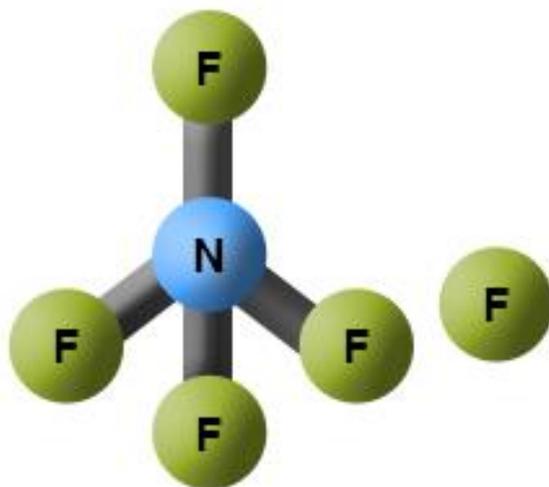


Figure 2

*Scientist 3*

It is not possible to produce  $\text{NF}_5$ . The size of the nitrogen atom is so small that it is impossible for five atoms of fluorine to fit around it with typical bond lengths.

**Questions 5.** A fourth scientist performed an experiment in which he produced a compound containing nitrogen and fluorine. The boiling and melting points of the new compound were observed to be low. Which scientist will likely think that this compound could be nitrogen pentafluoride based on the boiling and melting points of this compound?

- A. Scientist 3 only
  - B. Both Scientist 1 and Scientist 2
  - C. Scientist 2 only
  - D. Scientist 1 only
- 

**Questions 6.** Which of the following facts best supports the claim of Scientist 2?

- A. The compound  $\text{AsF}_5$  is known to exist.
  - B. The compound  $\text{NH}_4^+\text{Cl}^-$  is known to exist.
  - C. The compound  $\text{NH}_4^+\text{F}^-$  is known to exist.
  - D. The compound  $\text{PF}_5$  is known to exist.
- 

**Questions 7.** Which of the following facts best supports the claim of Scientist 1?

- A. The compound  $\text{NH}_4\text{Cl}$  is known to exist.
  - B. The compound  $\text{PBr}_5$  is known to exist.
  - C. The compound  $\text{NH}_4^+\text{F}^-$  is known to exist.
  - D. The compound  $\text{PF}_5$  is known to exist.
-

**Questions 8-9:**

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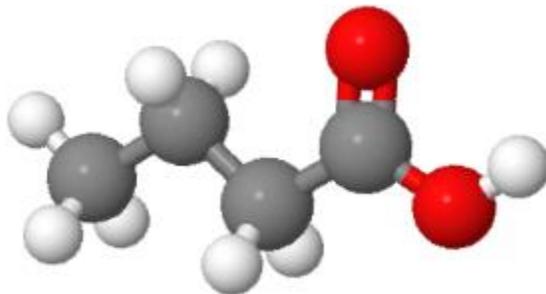


Figure 1

*Student 2*

The compound is ethyl acetate. The following model shows the structure of ethyl acetate.

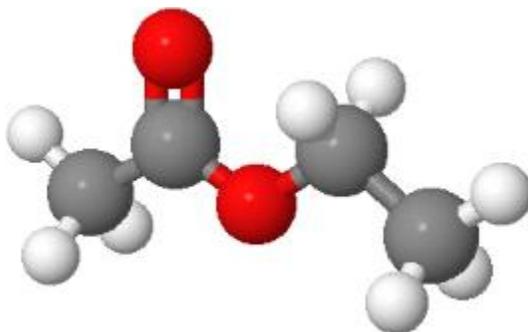
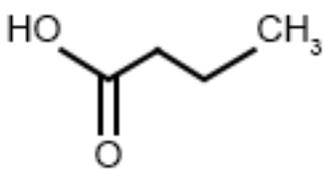
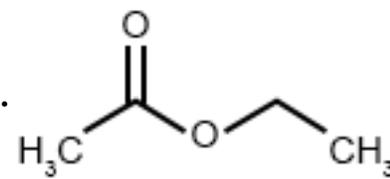
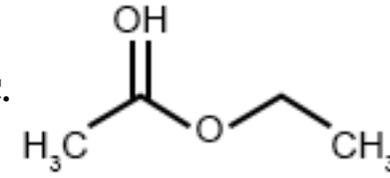
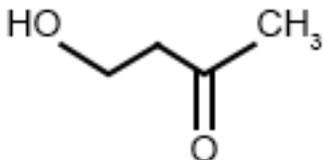


Figure 2

**Question 8.** Which of the following statements about the unknown compound will only Student 1 agree with?

- A. The oxygen atom of the compound has two single bonds with the carbon atoms.
  - B. Each molecule of the compound contains a chain of four successive carbon atoms.
  - C. The second carbon atom of the compound has a double bond with oxygen atom.
  - D. Each molecule of the compound contains a chain of alternate carbon and hydrogen atoms.
- 

**Question 9.** The students decide to identify the compound by its structural formula. Which of the following formulas of the unknown compound will Student 1 agree with?

- A. 
  - B. 
  - C. 
  - D. 
-

**Question 10:**

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**Question 10.** Which of the following statements best supports the classification of astatine as a nonmetal?

- A. Astatine is radioactive with a very short half-life.
  - B. At room temperature and pressure, and at 1 atmosphere of pressure, astatine is in the solid state.
  - C. Astatine is most likely a toxic element with a dull black color.
  - D. The chemical formulas of the known compounds of astatine are similar to those of the compounds of iodine.
-