

AP[®] CHEMISTRY
2010 SCORING GUIDELINES

Question 5
(8 points)

Use the information in the table below to respond to the statements and questions that follow. Your answers should be in terms of principles of molecular structure and intermolecular forces.

Compound	Formula	Lewis Electron-Dot Diagram
Ethanethiol	CH ₃ CH ₂ SH	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}:\ddot{\text{C}}:\ddot{\text{C}}:\ddot{\text{S}}:\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethane	CH ₃ CH ₃	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}:\ddot{\text{C}}:\ddot{\text{C}}:\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethanol	CH ₃ CH ₂ OH	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}:\ddot{\text{C}}:\ddot{\text{C}}:\ddot{\text{O}}:\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethyne	C ₂ H ₂	$\begin{array}{c} \text{H}:\text{C}::\text{C}:\text{H} \\ \text{or} \\ \text{H}-\text{C}\equiv\text{C}-\text{H} \end{array}$

(a) Draw the complete Lewis electron-dot diagram for ethyne in the appropriate cell in the table above.

See the lower right cell in the table above.	One point is earned for the correct Lewis structure.
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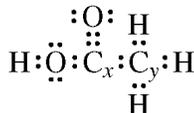
(b) Which of the four molecules contains the shortest carbon-to-carbon bond? Explain.

Ethyne, which contains a triple bond, has the shortest C-to-C bond. The other molecules have single C-to-C bonds, and triple bonds are shorter than single bonds.	<p>One point is earned for the correct choice.</p> <p>One point is earned for the correct explanation.</p>
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Question 5 (continued)

- (c) A Lewis electron-dot diagram of a molecule of ethanoic acid is given below. The carbon atoms in the molecule are labeled x and y , respectively.



Identify the geometry of the arrangement of atoms bonded to each of the following.

- (i) Carbon x

Trigonal planar	One point is earned for the correct geometry.
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- (ii) Carbon y

Distorted tetrahedral, tetrahedral or trigonal pyramidal	One point is earned for the correct geometry.
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- (d) Energy is required to boil ethanol. Consider the statement “As ethanol boils, energy goes into breaking C–C bonds, C–H bonds, C–O bonds, and O–H bonds.” Is the statement true or false? Justify your answer.

The statement is false. All of the bonds described are intramolecular; these bonds are not broken during vaporization. When ethanol boils, the added energy overcomes <u>intermolecular</u> , not <u>intramolecular</u> , forces.	One point is earned for the correct choice with justification.
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- (e) Identify a compound from the table above that is nonpolar. Justify your answer.

<p>Either ethane or ethyne may be identified as nonpolar.</p> <p>The ethane/ethyne molecule is nonpolar because all of the bond dipoles in the molecule cancel.</p> <p style="text-align: center;">OR</p> <p>The ethane/ethyne molecule is nonpolar because the molecule is symmetric.</p> <p><u>Note:</u> Explanation must refer to the shape of the molecule. Statements such as: “all hydrocarbons are nonpolar”, “the carbons are surrounded by hydrogens” or “there are no lone pairs” do not earn this point.</p>	One point is earned for a correct choice with justification.
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Question 5 (continued)

- (f) Ethanol is completely soluble in water, whereas ethanethiol has limited solubility in water. Account for the difference in solubilities between the two compounds in terms of intermolecular forces.

Ethanol is able to form strong hydrogen bonds with water whereas ethanethiol does not have similar capability. The formation of hydrogen bonds increases the attraction between molecules of ethanol and molecules of water, making them more soluble in each other.

Note: The answer must clearly focus on the solute-solvent interaction. Just the mention of hydrogen bonding does not earn the point.

One point is earned for the correct explanation.

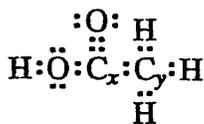
Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

5. Use the information in the table below to respond to the statements and questions that follow. Your answers should be in terms of principles of molecular structure and intermolecular forces.

Compound	Formula	Lewis Electron-Dot Diagram
Ethanethiol	$\text{CH}_3\text{CH}_2\text{SH}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \text{C} : \text{C} : \text{S} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethane	CH_3CH_3	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \text{C} : \text{C} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethanol	$\text{CH}_3\text{CH}_2\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \text{C} : \text{C} : \text{O} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethyne	C_2H_2	$\text{H} : \text{C} : : \text{C} : \text{H}$

- (a) Draw the complete Lewis electron-dot diagram for ethyne in the appropriate cell in the table above.
- (b) Which of the four molecules contains the shortest carbon-to-carbon bond? Explain.
- (c) A Lewis electron-dot diagram of a molecule of ethanoic acid is given below. The carbon atoms in the molecule are labeled x and y , respectively.



Identify the geometry of the arrangement of atoms bonded to each of the following.

- (i) Carbon x
- (ii) Carbon y
- (d) Energy is required to boil ethanol. Consider the statement “As ethanol boils, energy goes into breaking C–C bonds, C–H bonds, C–O bonds, and O–H bonds.” Is the statement true or false? Justify your answer.
- (e) Identify a compound from the table above that is nonpolar. Justify your answer.
- (f) Ethanol is completely soluble in water, whereas Ethanethiol has limited solubility in water. Account for the difference in solubilities between the two compounds in terms of intermolecular forces.

ADDITIONAL PAGE FOR ANSWERING QUESTION 5

5) b- Ethyne contains the shortest bonds. It is the only molecule given that contains a triple bond between the Carbons. Since triple bonds are shorter than double bonds which are shorter than single bonds, Ethyne must have the shortest C-C bond.

c- i. C₃: trigonal planar

ii. C₂: tetrahedral

d- ~~True~~ The statement is false. Ethanol boiling is a physical, not chemical, change, and thus intramolecular bonds (C-C, C-H, C-O, and O-H) are unaffected. Rather, the energy is used to break intermolecular bonds, such as hydrogen bonds and London dispersion forces; also dipole attractions.

e- Ethane is non polar. It is perfectly symmetrical on every axis, and thus has no dipole.

f- In ethanol, there is an H atom bonded to an O atom. This causes strong hydrogen bonds to form between the molecules in the liquid. The molecules of ethanol and those of water. In ethanethiol, on the other hand, the H atom is bonded to an S atom, which produces no hydrogen bonding. Thus ethanethiol can only interact with water via the weaker dipole-dipole interactions, and will not dissolve as readily.

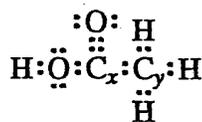
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Ethane	CH ₃ CH ₃	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \ddot{\text{C}} : \ddot{\text{C}} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethanol	CH ₃ CH ₂ OH	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \ddot{\text{C}} : \ddot{\text{C}} : \ddot{\text{O}} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethyne	C ₂ H ₂	H:C:::C:H

- (a) Draw the complete Lewis electron-dot diagram for ethyne in the appropriate cell in the table above.
- (b) Which of the four molecules contains the shortest carbon-to-carbon bond? Explain.
- (c) A Lewis electron-dot diagram of a molecule of ethanoic acid is given below. The carbon atoms in the molecule are labeled *x* and *y*, respectively.



Identify the geometry of the arrangement of atoms bonded to each of the following.

- (i) Carbon *x*
- (ii) Carbon *y*
- (d) Energy is required to boil ethanol. Consider the statement “As ethanol boils, energy goes into breaking C–C bonds, C–H bonds, C–O bonds, and O–H bonds.” Is the statement true or false? Justify your answer.
- (e) Identify a compound from the table above that is nonpolar. Justify your answer.
- (f) Ethanol is completely soluble in water, whereas ethanethiol has limited solubility in water. Account for the difference in solubilities between the two compounds in terms of intermolecular forces.

B B

B B B B B B

5B₂

ADDITIONAL PAGE FOR ANSWERING QUESTION 5

b. ~~ethane has the shortest carbon to carbon bond because~~

the other Ethyne has the shortest carbon to carbon bond because the carbons are triple bonded to each other not only one other H which has a very weak pull

or

i. trigonal planar

ii. trigonal pyramidal

so this statement is false. The bonds that are broken when boiled are intermolecular forces. Hydrogen bonding is broken as it boils

e. Ethyne is non polar because there are no unshared pairs of electrons and the bonds are balanced

f. Ethanol is more soluble because it doesn't have as ~~strong~~ strong hydrogen bonding as Ethane thiol

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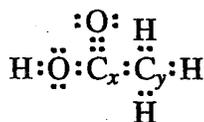
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Ethane	CH_3CH_3	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \text{C} : \text{C} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethanol	$\text{CH}_3\text{CH}_2\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} : \text{C} : \text{C} : \text{O} : \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Ethyne	C_2H_2	$\text{H} : \text{C} \equiv \text{C} : \text{H}$

- (a) Draw the complete Lewis electron-dot diagram for ethyne in the appropriate cell in the table above.
- (b) Which of the four molecules contains the shortest carbon-to-carbon bond? Explain.
- (c) A Lewis electron-dot diagram of a molecule of ethanoic acid is given below. The carbon atoms in the molecule are labeled x and y , respectively.



Identify the geometry of the arrangement of atoms bonded to each of the following.

- (i) Carbon x
- (ii) Carbon y
- (d) Energy is required to boil ethanol. Consider the statement "As ethanol boils, energy goes into breaking C–C bonds, C–H bonds, C–O bonds, and O–H bonds." Is the statement true or false? Justify your answer.
- (e) Identify a compound from the table above that is nonpolar. Justify your answer.
- (f) Ethanol is completely soluble in water, whereas ethanethiol has limited solubility in water. Account for the difference in solubilities between the two compounds in terms of intermolecular forces.

b. Ethyne contains the shortest carbon to carbon bond because it has 3 shared electron pairs compared to all the others which only have 1. With the addition of every shared electron pair, bonding becomes stronger and the atoms pull closer together

c. i. sp^2
ii. sp^3

d. the statement is true. Gas would be created in this reaction thus the bonds have to be broken. In this case by heat energy since it does require energy to boil ethanol.

e. Ethyne is non polar because it has a linear, symmetrical shape

f. C-OH bond is alot weaker than the C-S bond so C-OH is much more solvable while C-S is less solvable. Plus OH easily combines with water making it extremely solvable in water while S does not combine with water as well.

AP[®] CHEMISTRY
2010 SCORING COMMENTARY

Question 5

Overview

This question asked students to draw a correct Lewis electron-dot diagram for ethyne (C_2H_2) in part (a). In part (b) students were asked to compare the C–C bond lengths in three given Lewis diagrams and the fourth diagram drawn for part (a). In part (c) students were given a Lewis diagram for ethanoic (acetic) acid and asked to describe the geometry around each C atom. In part (e) students were required to identify one of the given (or drawn) Lewis diagrams that represent a nonpolar molecule and to justify why it is nonpolar. Parts (d) and (f) explored students' understanding of intermolecular forces: part (d) explored students' understanding of the interactions that are broken during vaporization, and part (f) probed students' understanding of the factors involved when a solute dissolves in a solvent.

Sample: 5A

Score: 8

This is an excellent response, with clear, concise answers. The answer to part (d) is admirable, as the forces holding the molecule together (the bonds) are clearly distinguished from the forces between the molecules (the intermolecular forces). The response to part (f) is also excellent, as it clearly indicates that the hydrogen bonding in the solution is between the ethanol and the water.

Sample: 5B

Score: 6

This is a good response that lost points only in the final two sections. One point was lost in part (e) for an inadequate explanation of why ethyne is nonpolar. The response to part (f) does not clearly indicate any interaction between either solute (the ethanol or the thioethanol) and the solvent water and thus did not earn a point.

Sample: 5C

Score: 4

The answers to parts (a) and (b) are straightforward and correct; in part (b) the terms “triple bond” and “single bond” do not appear, but the clean description of the shared-electron-pair model earned both points. In part (c) the hybridization of the central C atom is given, not the geometry, so no points were earned. The opening line, “the statement is true,” ruled out any point for part (d). The word “symmetrical” was enough to earn a point in part (e), but the confusion between intramolecular and intermolecular interactions lost the point in part (f).